IEA GEOTHERMAL

IEA Geothermal
Implementing Agreement

Germany
Country Report
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Germany

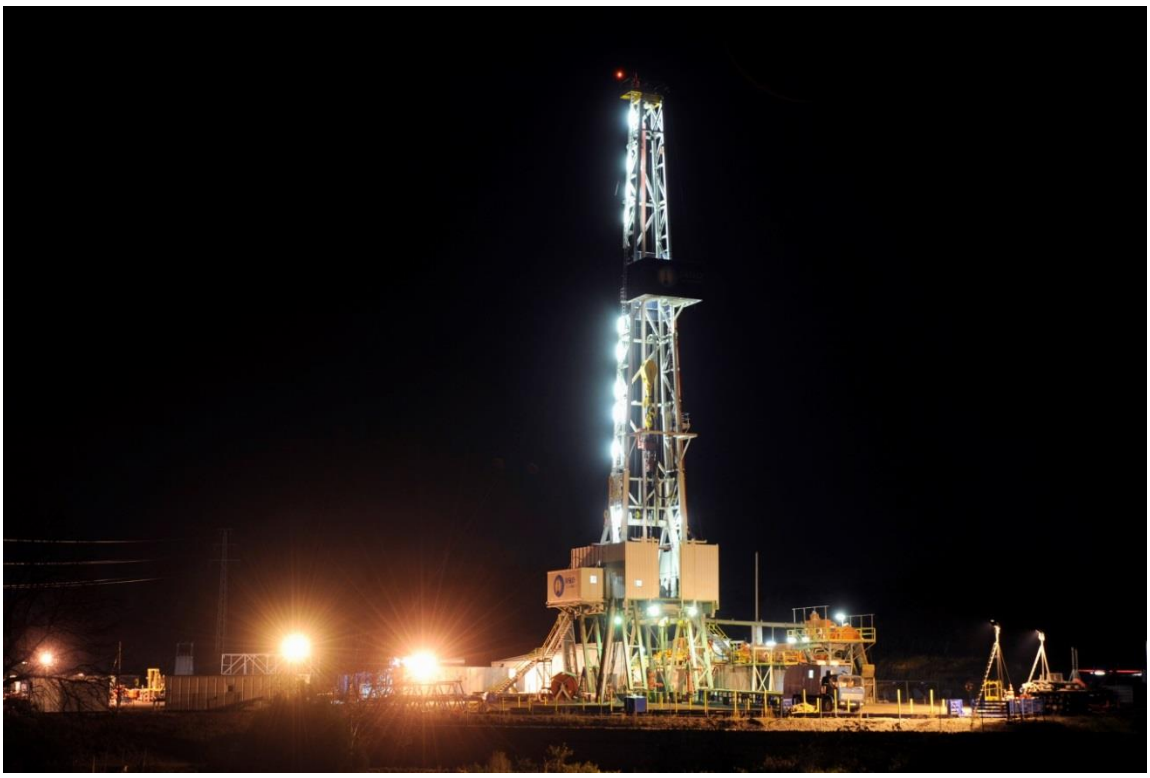

Figure 1 Geothermal drill rig at Insheim (Photo courtesy of BESTEC).

1.1 Introduction and overview

The use of geothermal energy offers significant potential and could theoretically meet Germany's energy demands several times over. Considerable efforts have already been made to tap into this potential, from exploration and development of particularly suitable regions and development of drilling technologies, through to systems for converting extracted geothermal heat into electricity.

In Germany, the Molasse Basin in the South, the Upper Rhine Graben in the Southwest and the North German Basin are most suited for geothermal development (Figure 2). According to the German Geothermal Association (BVG), there were 26 geothermal heating plants or combined heating and power plants in operation in Germany in July 2014, with an installed capacity of 300.4 megawatts (thermal), providing households, businesses and public buildings with thermal energy via district heating grids.

Figure 2 Geothermal regions in Germany.

In addition to the four geothermal power stations already operating in Insheim, Landau, Unterhaching and Bruchsal (Table

1), further geothermal plants were completed at sites in Dürrnhaar, Kirchstockach and Sauerlach (all in Bavaria) in 2014. This means that there are now seven geothermal power stations in operation to produce electricity, which have an electrical installed capacity of around 30 megawatts. Further power plants are currently under construction, for example, in Taufkirchen and Traunreut.

Table 1 Electricity-producing geothermal power plants in Germany in 2014.

Region	Location	MW el	MW th	Power Plant
Upper Rhine Graben	Landau	3.6	33	ORC
	Bruchsal	0.44	5.5	Kalina
	Insheim	4.3		ORC
South German Molasse Basin	Unterhaching	3.4	38	Kalina
	Dürmhaar	7.0		ORC
	Kirchstockach	5.5		ORC
	Sauerlach	5.0		ORC

In addition to these developments, numerous scientific and technical projects were also successfully completed in 2014 – these have contributed to significant gains in knowledge. In order to economically utilise deep geothermal energy and correspondingly exploit the existing potential of the heat, further research is still nevertheless required.

1.2 National Programme

The energy concept developed by the German federal government in 2010 envisages the far-reaching restructuring of the energy supply system in Germany by 2050. Important goals in this concept are the reduction of primary energy consumption by 50 percent, and increasing the proportion of renewable energies to cover 80 percent of the demand for electricity and 60 percent of the gross final energy consumption.

If the energy transition continues to run successfully, this concept will lead to an energy system in 2050 that is completely different to the current structure for the supply, distribution and demand for energy. The technologies that will be utilised in the realisation of this concept are to a large extent currently either not technically available or are economically infeasible. Energy research thus forms a strategic element of energy policy in order to generate technical innovations in the medium- to long-term that will enable the successful realisation of the energy transition.

In 2011, the 6th Energy Research Programme "Research for an environmentally friendly, reliable and affordable energy supply" was started. The goals of this programme are to accelerate the modernisation process for the German energy supply system, to strengthen German business in international competition, and to secure and expand technological options.

The 6th Energy Research Programme is oriented along the guidelines set by the energy transition. Increasing energy efficiency and renewable energy technologies has the highest priority. This is followed by storage and grid technologies, which will become increasingly important in future due to the growing use of fluctuating renewable energies.

The German federal government is resolutely pursuing the 6th Energy Research Programme in this legislative period by placing an even greater focus on the energy transition than ever before. An important measure is the bundling of applied project funding in the Federal Ministry for Economic Affairs and Energy (BMWi) as a vital element of the energy policy.

The BMWi is responsible for leading the 6th Energy Research Programme, and for funding applied research and technological developments in all energy technologies (except for bioenergy).

The basic principles for research funding are described in the 6th Energy Research

Programme. An overview of research activities and results is being published annually in a series of publications entitled "Innovation Through Research". Following the restructuring of energy research, this report will be the first in the series to cover the entire spectrum of research funding topics supported by the BMWi in the areas of both energy efficiency and also renewable energies.

1.3 Industry status and market development

Apart from funding carefully selected research projects, the Federal Government is also creating incentives for new projects by remunerating geothermal electricity under the Renewable Energy Sources Act (EEG) and by offering subsidies towards drilling costs. Since the amendment to the EEG was adopted by the Bundestag (Lower House of Parliament) in late June 2011, the framework conditions for promoting geothermal energy have been improved. Since then the feed-in-tariff has been fixed at 25 Euro-cents per KWh. The use of enhanced geothermal system (EGS) techniques has also attracted an additional subsidy of 5 Euro-cents per KWh since 2012. With these rates, the Government is hoping to encourage further advancement of geothermal energy.

The market incentive programme (MAP) of the German Government promotes renewable energy systems that provide space heating, hot water, cooling and process heat. It has a section for smaller buildings administered by the Federal Office of Economics and Export Control (BAFA), and one for large buildings and commercial uses, the latter being a premium component of the KfW Banking Group renewable energies program. Several geothermal technologies can be supported by the MAP; it subsidizes the installation of efficient heat pump systems in residential buildings and/through (?) repayment bonuses, depending on the installation size.

For heat and power plants using deep geothermal energy, a repayment bonus up to a maximum of 2,000,000 €/plant is granted. Well drilling accounts for a large amount of the total project costs. The repayment bonus for drill costs (only wells over 400 m) amounts to between 375 and 750 €/m, depending on the depth of the well. The maximum bonus per well is € 2.5 million. Furthermore, part of the exploration risk can be covered within a KfW Program.

For 2015, the market incentive programme and the EEG are under discussion. The tendency is that the support of deep geothermal energy generation by MAP will be increased, and the feed-in-tariff will be fixed at 25.2 Euro-cents per KWh. Also, the rate in the heat pumps sector will be revised.

The geothermal market predominantly comprises small and medium-sized mechanical engineering enterprises, as well as some large-scale enterprises, whose portfolios belong more to the classical energy sector, such as the hydrocarbon industry.

1.4 Research, development and demonstration/deployment

In order to tap the potential offered by geothermal energy as a continuously usable source of renewable energy, a great deal of research and development work has already been completed. Drilling technologies and the design of power plants, in which the heat extracted from the Earth is fed into district heating networks or converted into electricity, are being constantly improved. In addition, particularly suitable regions are being identified and opened up for development. Achievements can especially be seen in the Molasse Basin in Bavaria, where the supply of heat from deep geothermal energy can be reliably utilised. The aim in this region is now to increase the average output per power plant.

The range of funded projects in 2014 is very large: alongside projects designed to reduce exploration risk in the search for new

geothermal reservoirs, there are also a number of funded projects focusing on the development of alternative drilling processes or improving the pumps used for geothermal energy. Other projects conduct research into the behaviour of geothermal reservoirs or monitor existing geothermal power plants. The portfolio is rounded off by projects dealing with the issue of material corrosion or the performance of special components that form part of a geothermal power plant. The aim of the research is to collect operational experience and thus optimise the operation of future plants, as well as to further reduce the investment risk and the costs of extracting geothermal energy overall.

Figure 3 Drilling rig at Insheim (Picture courtesy of BESTEC).

Because of the significant potential and expected contribution of geothermal energy to a future energy system based on renewable energy, the BMWi is continuing to support relevant research projects.

The research projects currently being funded encompass all stages of the value chain for geothermal energy. The primary goal is to further reduce the cost of projects in order to make geothermal energy economically viable nationwide. Contributions toward the achievement of this goal are made by technological developments in all project phases: in the planning of the project, the exploration of the target region, the drilling/erection/construction work, and the testing and operation of the completed power plant. In particular, the deep boreholes must be completed more quickly and less expensively as they currently account for the main part of the investment costs. The operation of finished power plants must be more efficient, low maintenance and reliable. Alongside further technical developments in geothermal energy, concepts for improved public relations work are now a fundamental component of successful research projects. And last but not least, the conditions must be created for enabling geothermal energy to be utilised in those areas that have not yet been exploited or which prove less suitable.

In the area of geothermal research, the BMWi approved new funding for a total of 15 projects with a funding volume of around 12.7 million euros in 2014 (2013: 19.2 million euros). At the same time, around 15.6 million euros was invested in already ongoing research projects (2013: 17.1 million euros).

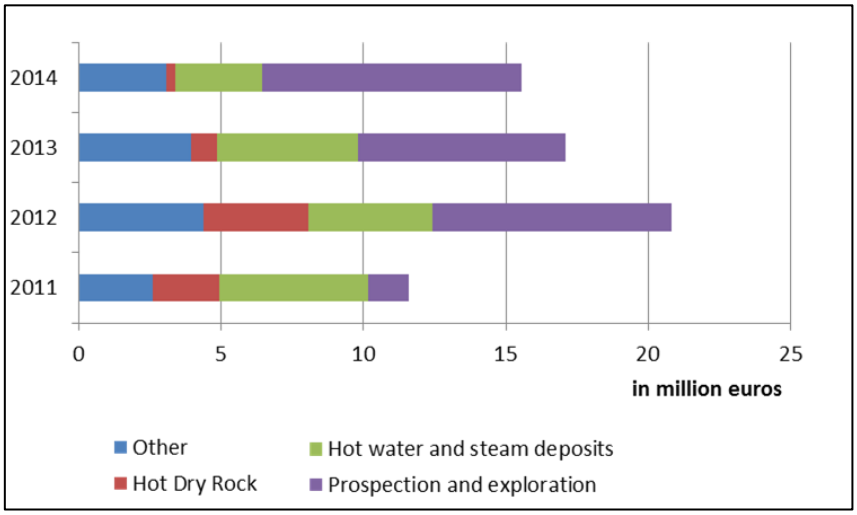

Figure 4 Distribution of geothermal energy-related research funding between 2011 and 2014.

1.4.1 Research Highlights

Innovative piping system for boreholes

Drilling a borehole many kilometres into the ground is very expensive. Innovative drilling methods seek to reduce the associated costs because it is these costs that significantly hinder the further expansion of deep geothermal energy as a technology for generating electricity in Germany. Baker Hughes INTEQ GmbH was able to demonstrate in their Geothermal Piping System project how drilling costs could be theoretically reduced by up to 30 percent. The researchers followed a holistic approach, investigating the three subject fields of monobore construction, automation of the drilling process, and borehole safety and integrity.

A borehole drilled using conventional technology starts with a large diameter and tapers as the depth increases – similar to a telescope. In contrast, monobore borehole construction produces a cased borehole with a uniform diameter from the top to the bottom by installing continuous piping in segments directly during the drilling of the borehole. This makes it possible to avoid using the casings previously necessary, as well as the round trips for their installation, resulting in faster drilling times, lower material usage and thus savings of up to 15 percent. The challenge faced in monobore construction is primarily the underground expansion of the installed casing pipe during the drilling to stabilise the borehole, as well as the underground connection of the pipes with a welding process instead of the usual threaded connectors.

The scientists were able to make considerable progress in these areas. The precise alignment of the individual components before the welding process and the achievement of a high-quality connection presented themselves as particular challenges in this process. In the project, a prototype for a welding robot was developed in cooperation with the Leibniz Universität Hannover, which is based on MIAB (Magnetic Impelled Arc Butt) welding technology and fulfills the requirements described above. The project partners were able to successfully complete the first tests of the welding equipment on original scale industrial applications.

In addition, the researchers developed a detailed concept for the automation of the drilling and piping process. With the aid of a specially developed algorithm, it was possible to find the optimal settings for the drilling system, such as drill bit load, speed and flushing rate, based on data measured underground. Applying this method can increase the drilling progress by 50 to 100 percent. In concrete terms, this resulted in cost reductions of up to 10 percent for one of the geothermal energy boreholes in the Molasse Basin in Southern Germany that had a typical end depth of around 4,500 metres.

The components for monitoring and controlling the integrity of the borehole are closely connected with this automation concept. Baker developed algorithms and programmes for improved modelling and prediction of the underground pressure conditions in both the rock and also the drilling fluid. The danger of borehole breakouts can be significantly reduced in this way.

A laser with a water jet for faster drilling

Another innovative approach for reducing drilling costs was initiated by the LaserJetDrilling joint project in cooperation with the Fraunhofer Institute for Production Technology IPT. The project partners aim to develop an alternative to the rotary method that has been predominantly used up to now by using a combination of water and laser jet drilling. In the case of the rotary method, a roller cone rotates on the end of a long drill string constructed out of individual pipes, whereby the rock is broken up mechanically. The process itself is extremely slow and causes a high level of wear to the drilling tools – with the entire drilling string needing to be completely dismantled a number of times for the replacement of components.

Drilling using a combination of water and laser jets is designed to enable deeper boreholes to be completed quickly and without any wear. Both processes complement each other: the laser beam makes it possible to quickly and efficiently remove solid rock, while water jet drilling enables fast tunneling, particularly through loose rocks. In order to protect the laser optics against contamination, the laser beam is directed through the water jet. The principle of water jet guided lasers has already been used for micro applications such as cutting silicon wafers, and the technology is available from the company Synova S.A., one of the partners in the LaserJetDrilling project. Other project partners include Herrenknecht Vertical GmbH, IPG Laser GmbH, KAMAT Pumpen GmbH & Co. KG and the International Geothermal Center (IGC) at the Bochum University of Applied Sciences.

Pump sensors monitoring operating conditions

Pumps are a critical element in the operation of a geothermal power plant. In comparison to their application in oil extraction, these pumps require significantly higher volumetric flows and performance, while crystalline precipitations such as calcite in the thermal water make their use more difficult. In their Centrifugal Pump project, Baker Hughes INTEQ GmbH is thus working on improving the reliability of electrical submersible centrifugal pumps for use in both the Molasse Basin in Southern Germany and the North German Basin. The project aims to redevelop critical components of the pumps and prove their effectiveness in long-term laboratory tests. The company is also utilising its high-temperature test rig for this work, which was developed during its earlier "Optimised Geothermal Pumps" project. This means that, for the first time, the long-term operation of up to 40 metre long high volume pumps with 2.5 megawatts of electrical output at water temperatures of a maximum of 190 degrees Celsius is now possible.

One focus of the new project is the development of a high-temperature pump sensor specially developed for geothermal energy. This sensor will be installed underneath the electric motor and is notable for its high dielectric strength and temperature stability.

1.5 Future outlook

Numerous efforts have already been made to develop the potential of geothermal energy as a continuously available renewable energy source. These include the exploration and exploitation of suitable reservoirs, the development of drilling technologies, and innovations in plant construction to ultimately use the extracted heat for power generation or heating purposes.

At the end of 2014 there were 31 deep geothermal wells for electricity and heating in operation, 6 under construction and 34 are planned.

The market for geothermal heat pumps has increased by 18,500 units with 196 MW to 316,000 units with 3,931 MW in total.

The area of Munich, situated in the Molasse Basin, is currently a booming area for the development of geothermal energy production. The municipal utility of Munich (Stadtwerke München) is planning to expand the district heating supply up to 100% for the city area. In the upper Rhine Graben, exploration activities are starting again.

The BMWi intend to increase the research funding for deep geothermal energy up to 30 M Euro for 2015.

The future outlook for the development of geothermal energy in Germany is therefore very bright.

1.6 Publications and Websites

Erneuerbare Energien: Innovation durch Forschung, Jahresbericht 2014 zur Forschungsförderung:
http://www.bmwi.de/DE/Mediathek/publi

kationen,did=703846.html
("Innovation Through Research 2014: Annual Report on Research Funding in the Renewable Energies Sector", English version expected in September 2014)

Federal Ministry of Economic Affairs and Energy: www.bmwi.de
BMWi publications in English: http://www.bmwi.de/EN/Service/publications.html

Project Management Jülich (Public Funding agency): https://www.ptj.de/renewable-energy

Database of all projects sponsored by the Federal Economics Ministry in renewable energies: www.forschungsjahrbuch.erneuerbare-energien.de

6th Energy Research Programme of the Federal Government: http://www.bmwi.de/EN/Service/publications,did=477502.html

EEG – Renewable Energy Sources Act: http://www.bmwi.de/EN/Topics/Energy/Renewable-Energy/2014-renewable-energy-sources-act.html

German Geothermal Association (BVG): http://www.geothermie.de/

Geothermal Information System for Germany (GEOTIS):http://www.geotis.de

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